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TEST DIRECTOR'S REPORT FOR
HEMP SIMULATION TEST,

Sanitized Version

T. J. Zwolinski

July 1992

CONTRACT NO. DNA001-91-C-0093

Prepared for:

**Director
DEFENSE NUCLEAR AGENCY
6801 Telegraph Road
Alexandria, VA 22310-3398
CDRL Item No. 10**

Prepared by:

**MISSION RESEARCH CORPORATION
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Colorado Springs, CO 80919
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4330 East West Highway
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FOREWORD

This report documents the on-site test activities for the Advanced Fixed-Ground Based Electromagnetic Pulse (EMP) Testing program (AFEMPT) High-Altitude EMP (HEMP) simulation test.

This document was prepared by Booz•Allen & Hamilton, Inc. for the Mission Research Corporation in accordance with CDRL 10 under subcontract SC-0093-91-0001 of prime contract DNA001-91-C-0093. The DNA project officer for this effort is Major Michael R. Rooney.

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SECTION 1 INTRODUCTION AND BACKGROUND

1.1 Introduction

This report describes the on-site test activities during the HEMP simulation test [REDACTED] between 18 May 1992 and 17 June 1992. Day-to-day activities, specific tests performed, and measurements made are described. Test results are provided from an operationally oriented viewpoint, i.e. what tests were accomplished in terms of the test objectives. These results are limited to the on-site observations of the test data. A detailed analysis of the data is in progress and the results of this analysis will be published in a separate report. A summary of operational lessons learned and recommendations is also provided in this Test Director's Report. This Test Director's Report is intended to provide the reader with an understanding of how the test was conducted and the conditions under which the measurements were taken. It does not provide conclusions obtained from the data except as they relate to any future test operations.

1.2 Background

The AFEMPT program is an element of DNA's Standards and Technology effort to develop a practical HEMP validation methodology. Specifically, the AFEMPT program supports this effort by providing EMP test integration assistance to DNA to ensure the understandability, effectiveness, and practicality of the test requirements and procedures as stipulated in MIL-STD-188-125 (Reference 1).

[REDACTED] tests and demonstrations sponsored by DNA have focused on the test requirements and techniques specified in MIL-STD-188-125 which relate to the E1 or early-time portion of the HEMP environment defined in DOD-STD-2169A (Reference 2). Recently, under DNA sponsorship, pulse generators have been designed and developed which are capable of producing the test injection waveforms stipulated in MIL-STD-188-125 for the E2 (intermediate-time) and E3 (late-time) portions of the HEMP environment.

[REDACTED]

As a target of opportunity an additional objective was incorporated into the [REDACTED] test which addressed coupling of the radiated E1 environment to communications antennas. [REDACTED]

[REDACTED] CW illumination tests were conducted to provide data to support pulse test requirements for RF antenna lines as specified in MIL-STD-188-125.

1.3 Document Contents

In addition to this section, this report includes the following:

Section 2. Test Summary which defines the specific test objectives, the test techniques used and summarizes the test accomplishments in terms of the objectives.

Section 3. Chronology which provides a day-by-day summary of test activities.

Section 4. Measurement Summary and Results which provides a complete listing and description of all measurements made along with a summary of on-site test results.

Section 5. Recommendations and Lessons Learned during the course of test execution as they relate to test conduct activities.

SECTION 2 TEST SUMMARY

2.1 Test Objectives

[REDACTED]. Three of these objectives relate to the E3 environment as follows:

Objective E3-1. Determine the requirements [REDACTED]
[REDACTED]

Objective E3-2. [REDACTED]
[REDACTED]

Objective E3-3 [REDACTED]
[REDACTED]

One objective was posed for the E2 environment comparable to objective E3-2:

Objective E2-1 [REDACTED]
[REDACTED]

The final objective related to antenna coupling of the E1 environment:

Objective CW-1. [REDACTED]
[REDACTED]

2.2 Test Techniques

The test techniques employed in the course of the [REDACTED] test are summarized here for each specific objective. Greater detail concerning equipment configurations, types of data acquisition equipment used, etc. is provided in Section 4, Measurement Summary.

[REDACTED]

[REDACTED]

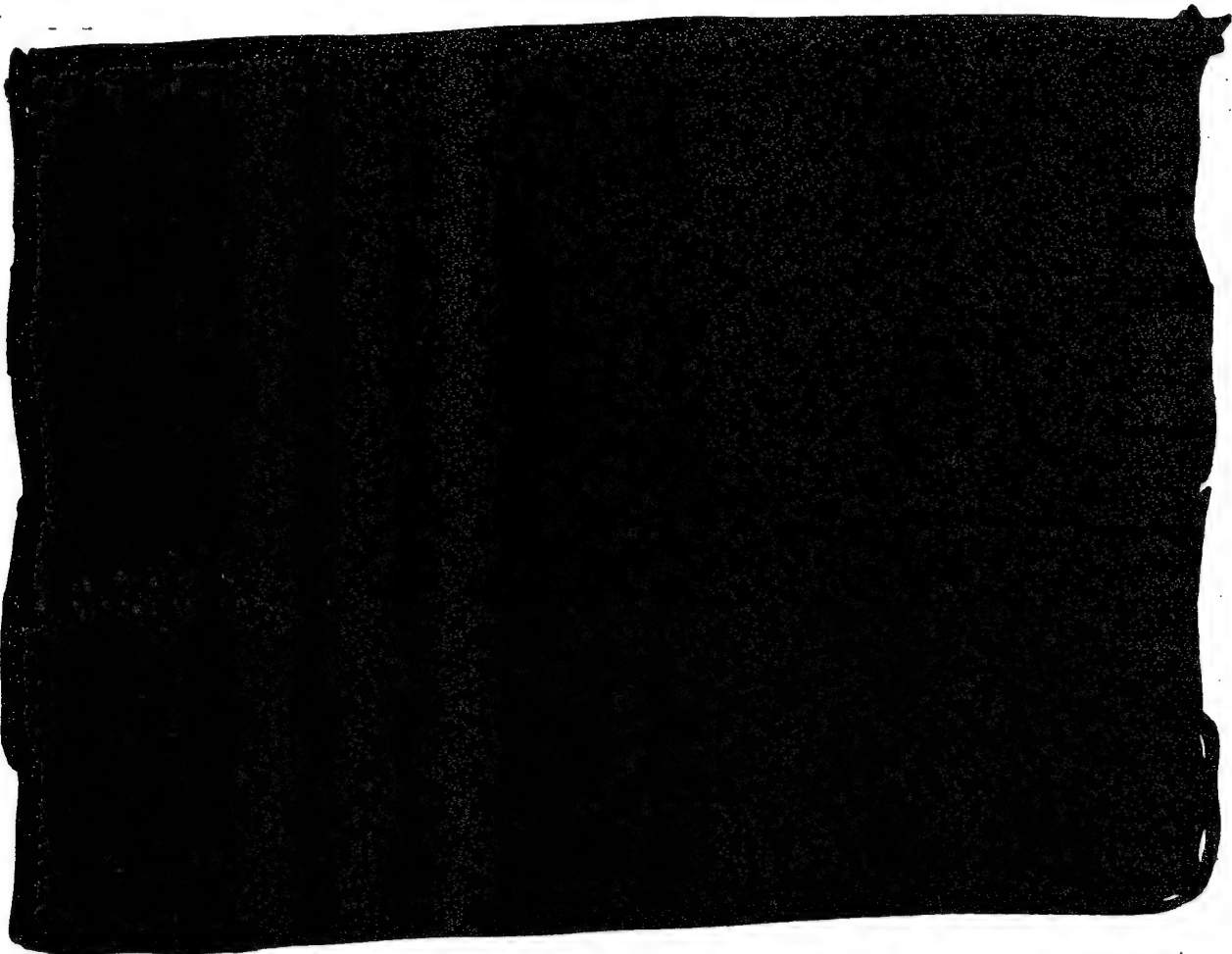
Objective CW-1. Response of Communications Antennas. The CW Measurement System (CWMS) was employed for these tests. The CWMS vertical and horizontal antennas were used to illuminate [REDACTED] facility antennas [REDACTED]. Measurements of the short circuit current and the current into a fifty ohm load were made in the facility radio room at the end of the coaxial cable from each antenna. Two angles of incidence were employed for [REDACTED] antennas i.e., the [REDACTED]

[REDACTED]

2.3 Test Accomplishments

In general the test was a success and all planned objectives were addressed. Approximately 95% of the planned measurements were made. Some of the antenna illumination tests were not accomplished primarily because the reconfigurations of the CWMS antennas and the setup to measure the [REDACTED] and near the antennas required more time than planned. Inclement weather also slowed operations on several days. The test was completed within the scheduled time period (four weeks) with excellent support from site personnel.

A brief summary of the results for each test objective are given below. Detailed post-test analysis of all the data is required to draw firm conclusions for each test objective. The results presented here are based on the on-site observations only and any quantitative statements are subject to revision.



Objective CW-1. Response of Communications Antennas. Sufficient data was obtained to determine the response waveform of the various antennas. Post-test analysis is required to evaluate the impact of these measurements on pulse test requirements of MIL-STD-188-125.

SECTION 3 TEST CHRONOLOGY

3.1 Introduction

This section presents a day-by-day compilation of significant test activities. The number and types of measurements acquired each day are also provided.

3.2 Daily Test Activities

18 May The E3 pulser and the [REDACTED] generator to power the pulser arrived on-site and were set up at the East end of the facility parking lot. A safety area was cordoned off by site personnel. The E2 pulser and some associated equipment were also delivered. The E3 pulser checkout procedure was accomplished and the only measurements made were pulser calibration measurements into a 50 ohm load.
[REDACTED]

19 May E3 pulser calibrations were completed with tests into 1.4 ohms and a short circuit. [REDACTED] Initial [REDACTED] injections were begun at 1510 hours in support of objective E3-1. A series of four pulses ranging from about 190 V to 950 V charge voltage were accomplished. Currents were monitored on the pulser output and return and ranged from about 30 amperes to about 170 amperes. Six good data records were acquired; the data was off scale for one of the tests. No facility disturbances were noted. Internal test points for this objective were identified.

20 May [REDACTED] injection testing continued. The 200 ampere current level was achieved [REDACTED] No disturbances were reported. [REDACTED] to begin internal measurements [REDACTED] After several measurement attempts it was found that keying the handie-talkie radios was interfering with the measurements. A procedure was established in which no radio keying was performed after t-5 seconds and valid data was acquired for two injections and two test points. One of these injections was a series of ten second "on", ten second "off" periods to establish correlation of the measured response with the E3 pulse. Ambient noise and pick-up noise measurements were also made. A total of ten valid data records were taken in the facility. Two records of the pulser output and return current were also made.

21 May [REDACTED] injection testing continued. The response and ambient noise was monitored on nine additional test points with repeatability data taken on one. No facility disturbances were reported and the injection configuration was changed [REDACTED] Measurements of the pulser output and return currents were made for two charge voltage levels. A total of 20 valid measurements were made.

22 May

[REDACTED] The two test points showing the largest responses in the injection were monitored and no response was seen. A second injection configuration was established [REDACTED] and the two points were repeated. The responses were lower than for the injection across the larger dimension [REDACTED] It was decided that no further information could be obtained for this objective and the remainder of the day was spent siting locations for the CWMS antennas. [REDACTED] A total of seven valid data runs were obtained.

25 May

Memorial Day holiday. No test activities.

26 May

Setup was initiated for tests under objective E3-2 [REDACTED] However due to heavy rain it was deemed unsafe to operate the E3 pulser. The balance of the day was spent doing preliminary setup of the CWMS antenna at test plan location number 2. This effort included clearing the area of salvage equipment, measuring stake locations and driving stakes, and moving antenna parts to a staging area.

27 May

[REDACTED] there was no measurable current [REDACTED] The differential mode drive was set up and conducted [REDACTED]. Since the same transfer function [REDACTED] was observed for the drive [REDACTED] Twenty-four data records were obtained with drives at two pulser levels for each test point to demonstrate linearity of the transfer function. In order to preclude damage [REDACTED] the injected currents were limited [REDACTED] The CWMS vertical antenna set up at location 2 was conducted in parallel and completed.

28 May

Tests for objective E3-3, [REDACTED] were performed. The facility was cycled to generator power so that the E3 pulser could safely be connected [REDACTED] The facility was returned to commercial power after the connection was made and although about 27 amperes of AC current was being drawn by the pulser neither the pulser [REDACTED] reacted adversely. T [REDACTED] No evidence of

facility responses were seen.

E3 testing was completed at about 1300 hours with the acquisition of 18 data records. Set up of the E2 pulser was initiated, but no valid data was obtained.

29 May

Testing for objective E2-1 was conducted. The drives were accomplished in the same manner as for the E3 tests and data was recorded using the S-cubed pulse data acquisition software installed in a lap-top computer with the transient digitizers. No fiber optic telemetry links were used. Common mode injections and differential injections were made. A total of 22 data records were obtained. Each data record includes a measurement of the injected current and the response. No problems were encountered in this test.

1 June

Set up of the instrumentation configuration for the antenna response tests was performed including routing a fiber-optic voice link and erecting a thirteen meter high support mast for the reference field sensors. The reference field was monitored at this height for all antennas since the antennas are at least 13 meters above ground. The only data obtained was a reference field measurement for the communications tower antennas.

2 June

In the morning, a demonstration of the E2 pulser drive. During the afternoon, CW measurements were re-initiated but due to RF amplifier drop outs only one valid measurement was made.

3 June

Due to the amplifier drop-out problem and the potential risk of damage associated with frequent raising and lowering of the reference sensors, a decision was made to use a "live" 1 meter high reference as opposed to a stored reference. (Amplifier drop-outs are readily detectable only in the reference channel.) The transfer function between the 13 meter and 1 meter reference would be recorded for post-test processing. It was later determined that the amplifier drop out was due to RF EMI affecting the new AC generator used for the RF amplifier. This generator has electronic control circuitry and when relocated about 30 feet from the CWMS antenna, the drop outs ceased to occur. Ten measurements for the tower antennas were made including ambient noise for each. The 13 meter reference tower was moved to a position for measurement of the #10 fan-doublet antenna.

4 June

Measurements were made for the number 10 and number 9 [REDACTED] antennas. A total of nine measurements were made including pick-up noise, two 13 meter references, and two reference response measurements at the 1 meter height. Ambient noise data were obtained for the four antenna measurements.

5 June

[REDACTED]. The day was spent doing preliminary set up of the [REDACTED] antenna [REDACTED] including brush clearing and staging of the antenna elements [REDACTED]. No measurements were made.

8 June

[REDACTED]. No further tests on this antenna were attempted. The deployment of the CWMS horizontal antenna at test location 2 was completed as was movement of the reference tower [REDACTED]. The high frequency D-dot sensor was damaged in transport and the rental generator for the CWMS van ran out of fuel in the early afternoon. A fuel delivery which had been scheduled to occur on Friday (5 June) did not arrive.

9 June

Repair of the D-dot sensor was accomplished using a metal-epoxy adhesive. However, no additional test time was lost to this repair since site operations in the antenna area precluded testing until noon. Measurement of the reference field for the horizontal polarization indicated the presence of nulls in the field at the 13 meter height near 40 MHz and 80 MHz. The source of these nulls could not be resolved. Three measurements including one pick-up noise run were made [REDACTED] #10. Data for [REDACTED] #9 on this date is erroneous since the wrong reference orientation was used.

10 June

Measurements for [REDACTED] #9 were repeated using a "live" reference at the 13 meter height in the interest of test efficiency. Attempts were made to define the source of the nulls in the 13 meter reference without success. The nulls do not appear at 1 meter or at three meters and could not be traced to measurement technique problems. The reference tower was moved for horizontal polarization measurements of the communications tower antennas. These unplanned measurements were conducted since it appeared that we gained some schedule time [REDACTED]. Two valid test runs and two reference checks were made.

11 June

Six measurements were made for the three [REDACTED] antennas completing all CWMS location 2 measurements. The reference for these data shows an interfering signal of varying amplitude at about 870 MHz. Movement of the CWMS antenna to test location 1 was begun.

- 12 June The day was spent moving the CWMS antenna. The decision was made to set up the horizontal array only. This was based on the information we received that we would not be allowed to test on Monday morning (15 June) due to site mission activities and if we set up the vertical array first there might not be time to set up and perform horizontal tests. The antennas of interest at CWMS location 1 are horizontally polarized. Further the wires which form the vertical dipole would have to be pre-hung on the tower as it would take a full day to lower and raise the tower if not pre-hung; if this were done any wind would likely twist the wires and they cannot be untwisted from the ground.
- 15 June Per site direction, no testing was performed until afternoon. Horizontal antenna deployment was completed as was erection of the reference tower for measurement of [REDACTED] 11 and 12. In the afternoon four antenna measurements and the reference sensor measurement were made.
- 16 June The reference tower was moved for measurements of the [REDACTED] antenna. The reference transfer function was measured along with four measurements on the [REDACTED] antenna. The short circuit and 50 ohm currents were monitored for boresight incidence and side-on incidence. This completed the planned antenna response measurements. The reference tower was moved to a position to perform a full six component field map of the horizontal antenna at the 13 meter height.
- 17 June The 13 meter height field map was performed in the morning and six measurements were recorded. Packing of equipment for shipment was begun.
- 18 June Equipment packing was completed and equipment shipped to S-cubed in San Diego.

SECTION 4 MEASUREMENT SUMMARY AND RESULTS

4.1 Introduction

This section provides descriptions of the measurement configurations used in the test. Descriptions of the data acquisition equipment and procedures are included. Test results which are based on on-site examination of the data records are also summarized.

4.2 E3 Simulation Tests

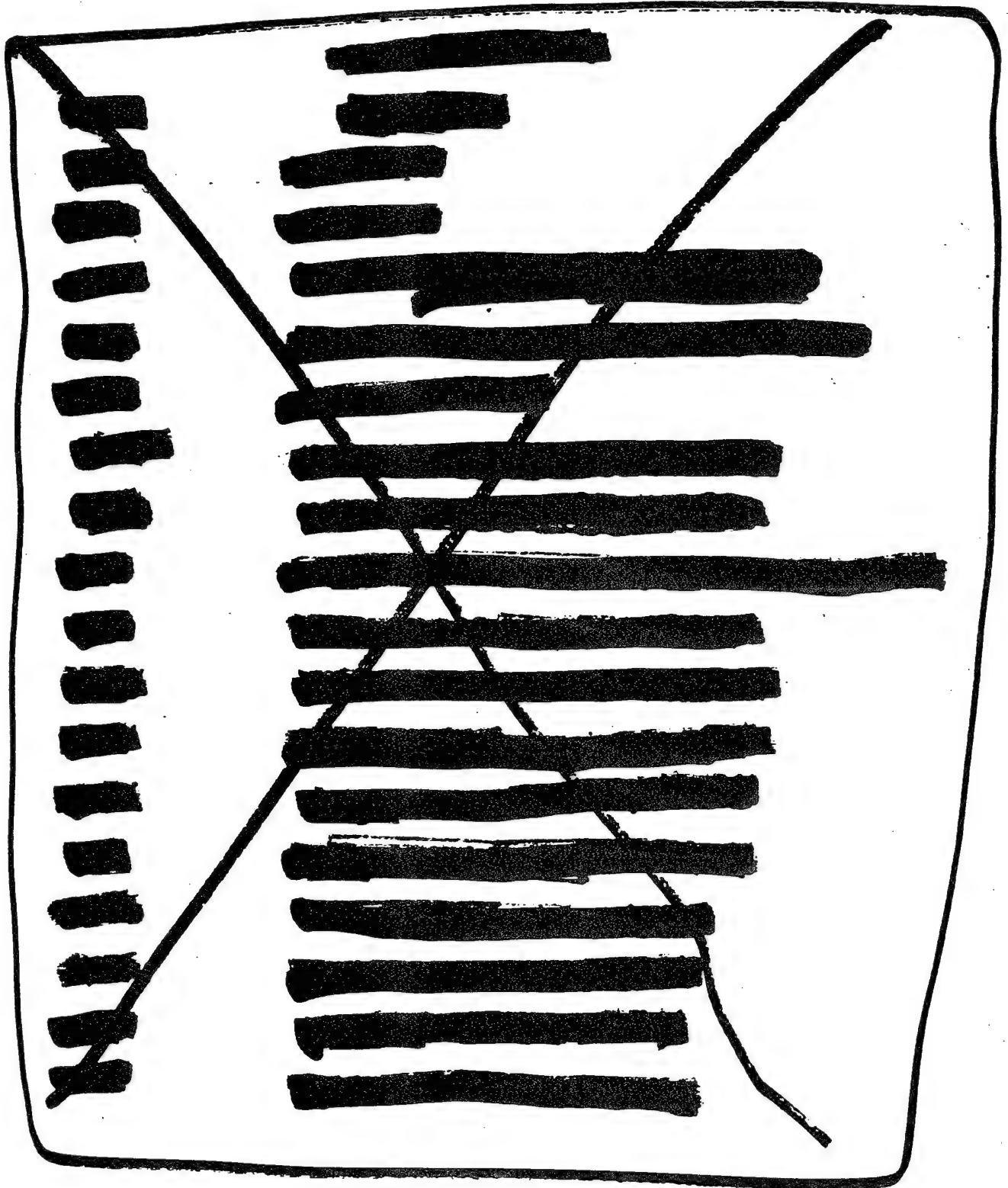
The E3 simulation tests were performed using the DNA E3 pulser which produces the "long time" pulse waveform as specified in MIL-STD-188-125. The pulser output amplitude is varied by limiting the charge voltage. This produced injected currents ranging from about amperes to over amperes depending on the impedance of the driven circuit.

The pulse was delivered to the injection points via several hundred feet of 250 MCM cable which was connected using welder's clamps or standard electrical lugs depending on the injection point. All data was acquired using an Astro-Med Inc. recording digitizer. This device produced strip chart records for on-site evaluation. The data was transferred to floppy-discs via a portable computer for post-test analysis. Since the full E3 pulse lasts for about six minutes, these data records are very long (several thousand bits). In many cases "short" records (10-30 seconds) were acquired for test set up purposes and on-site diagnostics in order to avoid excessive data storage problems. The few megabyte hard-disc storage of the portable computer could be filled in a few hours of testing and would have to then be archived on the floppy-discs. This process required almost 15 minutes per record.

A unique coding system was used for the E3 data records. An eight character filename was employed in all cases. The first character is the number 3 indicating that the data is for E3 tests. The second character is a letter A, B, C, which correspond to increasing charge voltages i.e., charge level C is greater than level B which is greater than level A. The character Y was used as the second character for ambient noise measurements (zero pulser charge). The third character is a zero in most cases. Where the letter N appears as the third character, a pick-up noise measurement is indicated. The fourth through sixth characters correspond to a specific test point. The complete list of test points are provided below. The seventh character is a repeat indicator: the first pulse is always A with B, C, etc. used for subsequent pulses. The last character indicates the type of measurement made and is either C for current or V for voltage. Thus the file "3A0025BC" indicates an E3 test at the initial charge level for test point 025: this is the second measurement of the current.

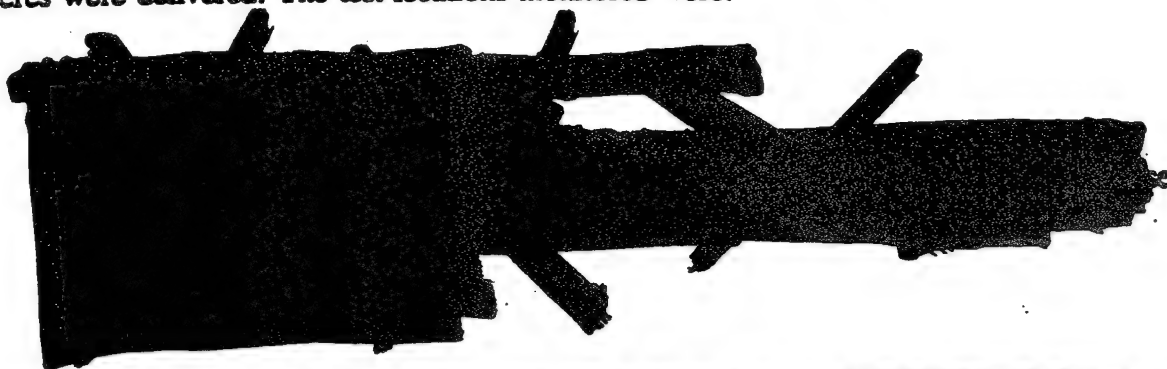
In that case the first character is a G, ; the seventh character is a repeat indicator, and the last indicates current (C) or voltage (V). Table 1 is a list

of all test points and their associated code.



[REDACTED]

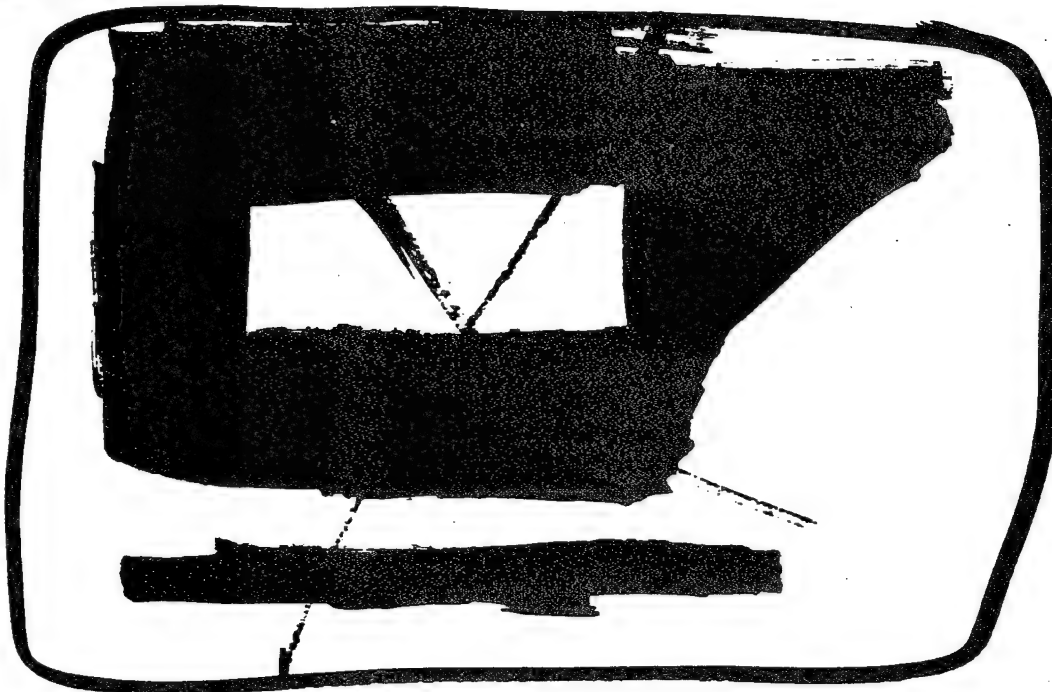
For injection [REDACTED] currents as high as 205
amperes were delivered. The test locations monitored were:



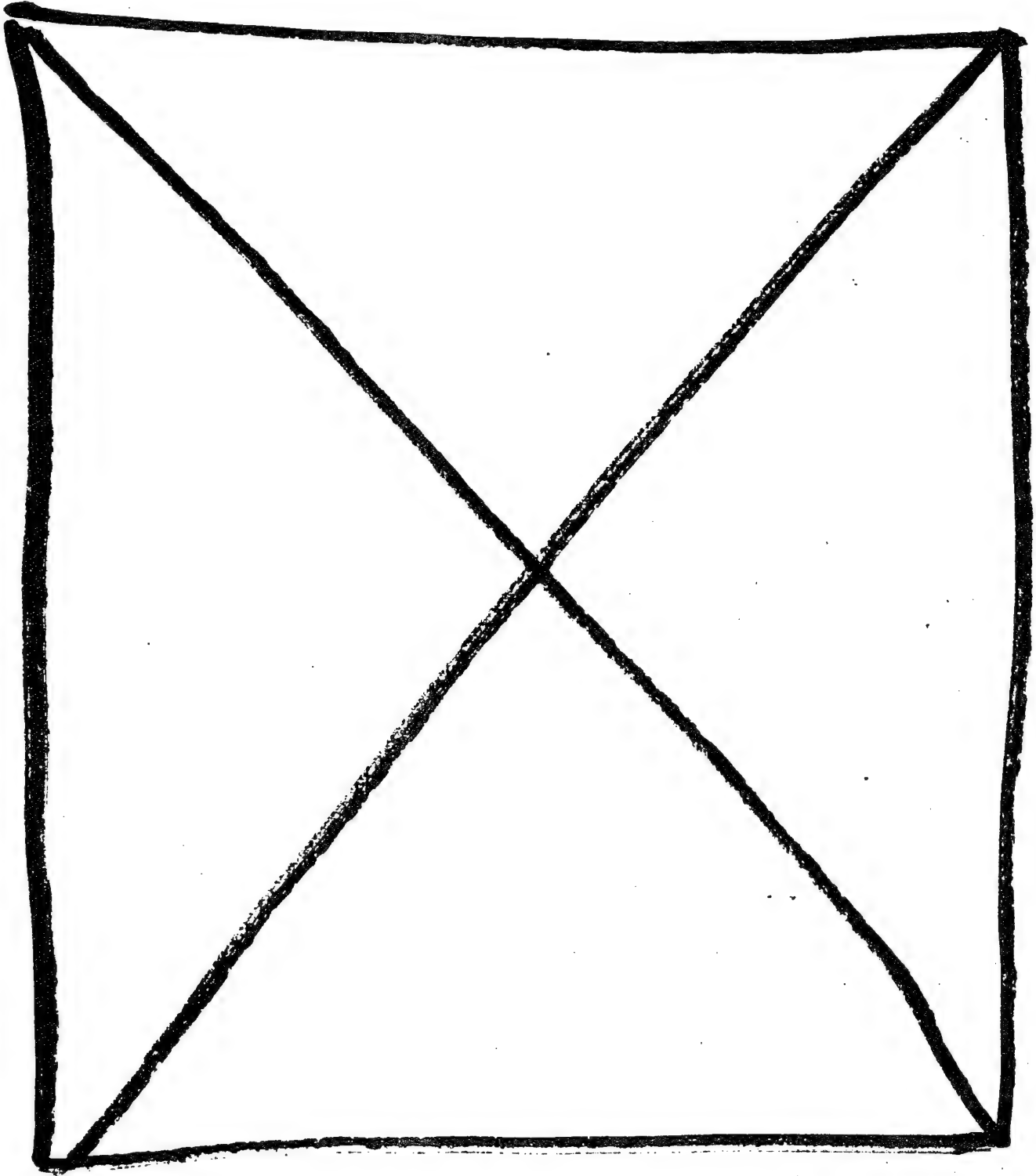
011 current
019 current.


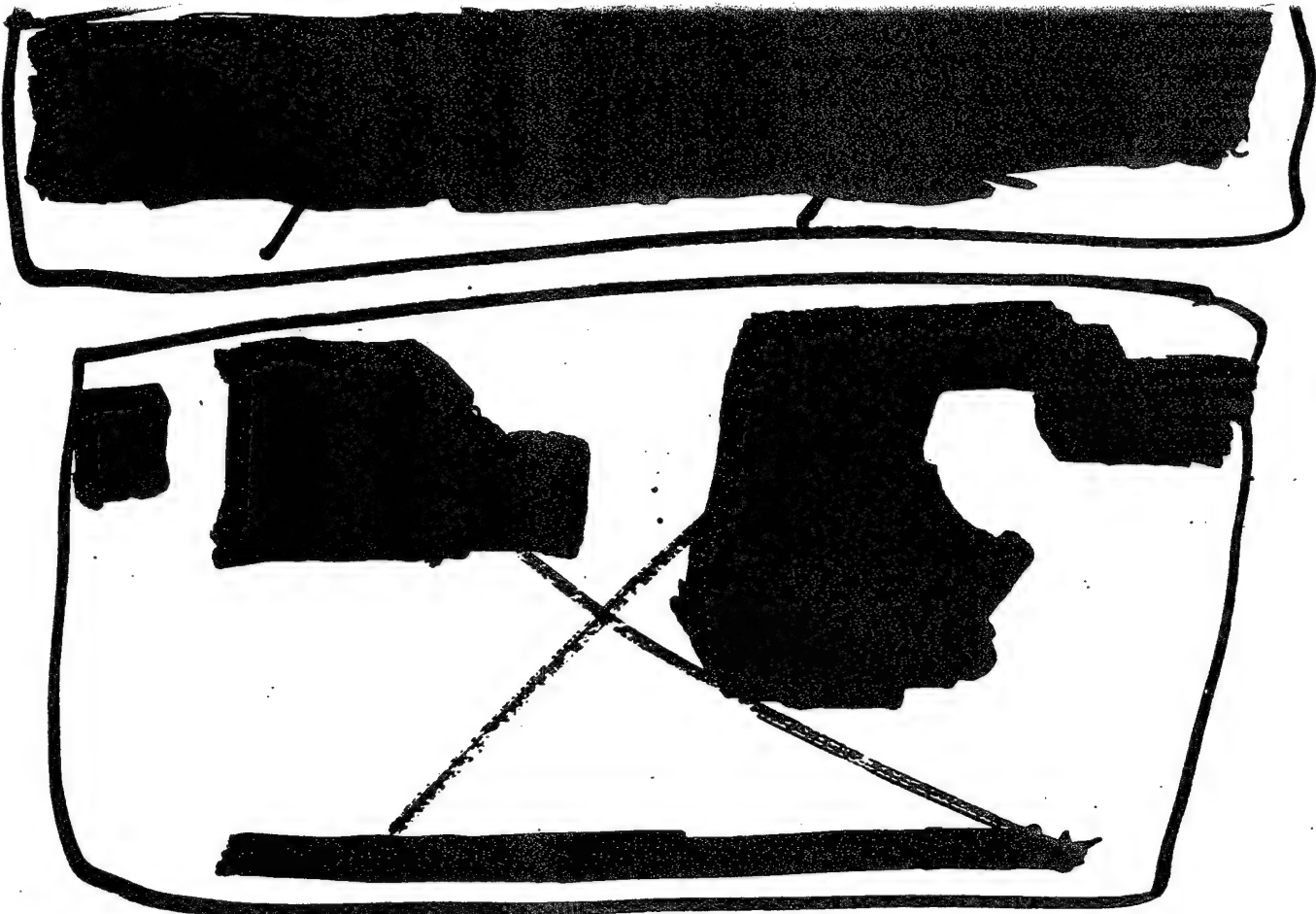


011 and 019 current.



The maximum internal response [REDACTED] was observed on location 011 in configuration [REDACTED]. For configuration [REDACTED] no measurable signal was seen. [REDACTED] the response at 011 was reduced by about half. No disturbances were reported throughout the conduct of these tests.






The E2 simulation tests were performed using the DNA E2 pulser which produces a waveform in accordance with the MIL-STD-188-125 test injection requirement for the "intermediate-time" pulse. The pulser output current is varied by varying the charge voltage. the test charge voltages ranged from 1 kV to 8 kV resulting in drive currents from about 50 amperes to over 400 amperes. Although charge voltage headroom was available no attempt was made to inject the specified 500 ampere pulse as a precaution.

Linearity of the response was demonstrated by testing at two charge voltages. In general testing was conducted at 4 kV for common-mode injection and at 1 kV for differential mode injection.

The pulse delivery system for the E2 waveform is somewhat more sophisticated than that used for E3 because of the higher frequency content in the E2 pulse.



Data was recorded on HP54111 digitizing oscilloscopes [REDACTED]. The digitizers were controlled by a lap top computer using the same software for control and data storage as the pulse data acquisition system [REDACTED]. Measurements were made using a Pearson 1114 solid core (not clamp-on) current probe connected to the digitizers via double-shielded coaxial cables.

The test points for E2 tests are listed in Table 2. The filenames for the data are simply the three character test point code given in Table 2 followed by the letter A through K for repeats (the first measurement has no letter suffix) and the letter U for pick-up noise. Ambient noise measurements were not made [REDACTED].



E2-1 [REDACTED] The test configurations for the E2 common and differential mode drives were identical to those shown in Figures 3a and 3b for the E3 tests [REDACTED].

The common mode drive was connected to E26 and current measurements were made of the input drive and at test points E23, E24, E25, E27, E28, E29, and E210. A pick-up noise measurement near E29 was also made. The transfer function was linear between a 4 kV and an 8 kV charge voltage and was about 1:210.

The following sets of measurements were made for differential mode drive [REDACTED]

Drive E25; Measure E27, E28, E29, E210

Drive E24; Measure E27, E28, E29, E210

Drive E23; Measure E28, E29

The measurement sequence for drive of E23 [REDACTED] was curtailed since the responses seen were in qualitative agreement with the injections [REDACTED]. A transfer function of about 1:3 was observed [REDACTED]

In all the E2 tests [REDACTED] the input pulse was shortened to about 20 microseconds as opposed to a 20 millisecond pulser output when driven into a short. It is conjectured that this pulse shortening [REDACTED]

4.4 Antenna Response Tests

The antenna response tests were performed using the DNA CWMS equipment [REDACTED] site [REDACTED] antennas were illuminated with horizontally and /or vertically polarized fields [REDACTED]

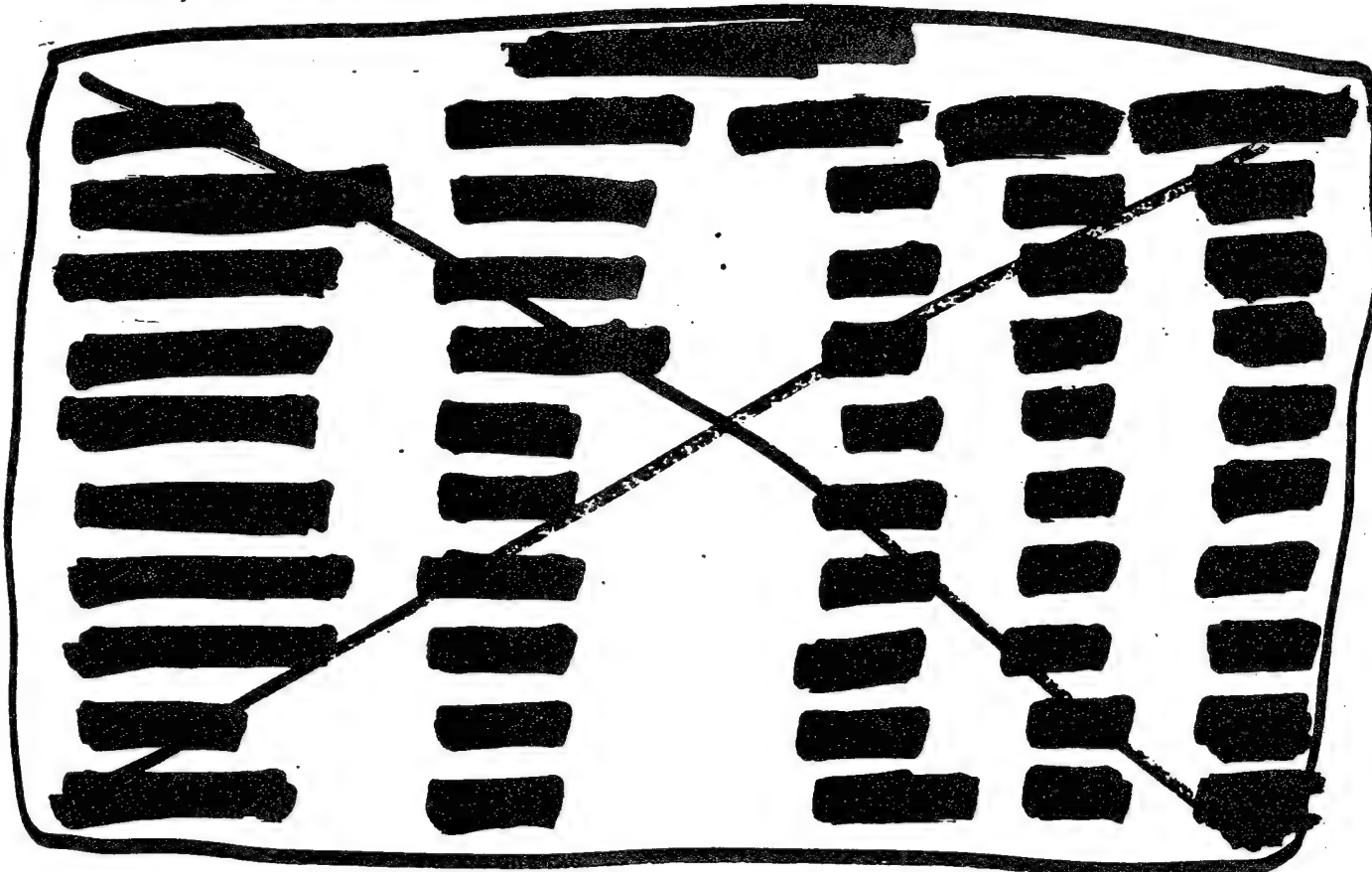
The antenna responses were monitored [REDACTED]. The antenna coaxial cables were terminated in both a 50 ohm load and a short circuit for each polarization/orientation configuration. [REDACTED]

[REDACTED] Figure 5 (taken from reference 3) shows the approximate relative location of the CWMS antenna [REDACTED]. Obviously, although a measurement was being made on one antenna, all the antennas are illuminated to some degree. [REDACTED]

[REDACTED] Thus while monitoring, [REDACTED] the communications antennas are also being excited [REDACTED]. While their contribution to the response may be small, it should not be surprising to observe "non-causal" responses in terms of the propagation distance [REDACTED]. Table 3 below provides approximate cable lengths for all the measured antennas.

The reference field data for all the antennas was monitored at a height of 13 meters above ground. The approximate height of the antennas is provided in Table 3. The reference sensor was located in the vicinity of the antenna under test as listed in Table 3 and as shown in Figures

[REDACTED] "live" reference was desired (as opposed to a stored reference) and it was considered a risk to raise and lower the reference sensor numerous times. Therefore the transfer function from the 13 m height to a field sensor mounted on a one meter stand was measured. The one meter reference was then used for antenna response data acquisition. This technique was used in all cases except horizontal polarization. [REDACTED] # 9 (test files H031A and H032A). A 13 meter "live" reference was used for these files.



The only data obtained on-site consisted of frequency domain transfer functions. Due to software problems extrapolated responses and time domain responses could not be obtained. Therefore the results of these tests will not be available until after post-test analysis. All the necessary information from which to determine response waveform parameters is available [REDACTED]

Table 4 provides a list of all measured responses including the 1m/13m reference transfer functions. Figures 6 through 11 show pertinent geometry relationships of the CWMS antenna, the antenna under test, and the reference sensors.


Table 4. CW Data Files

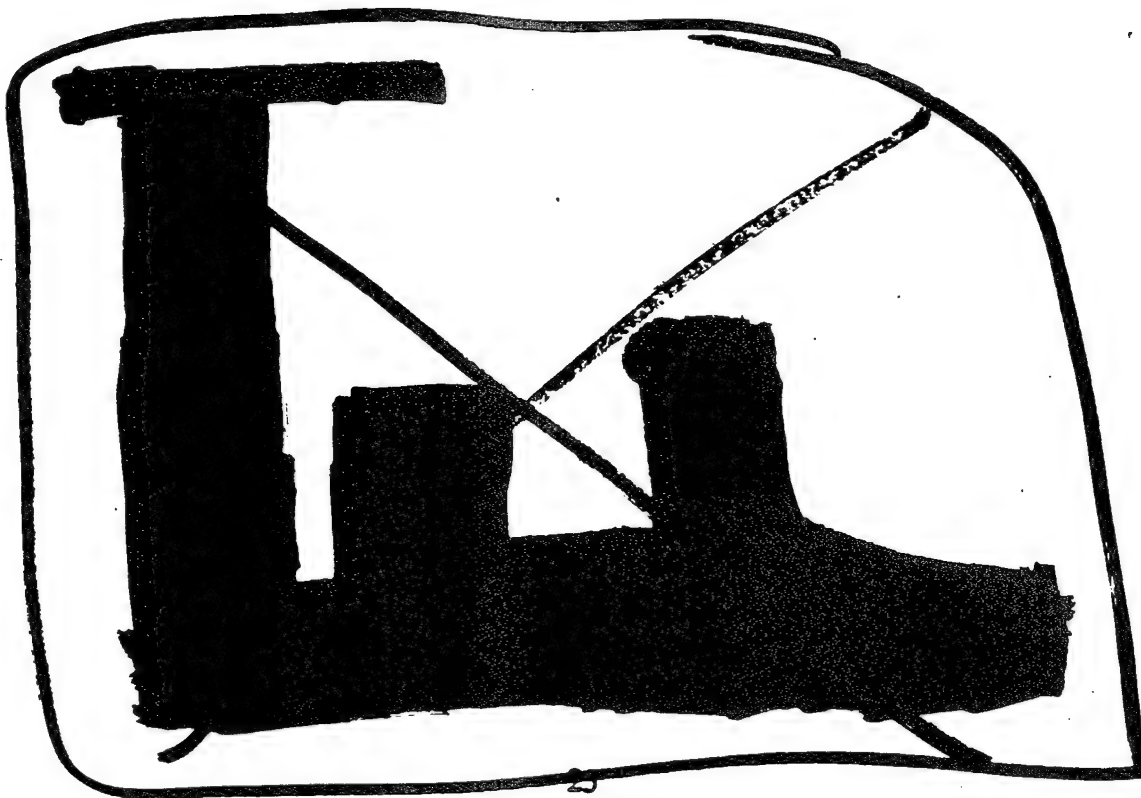
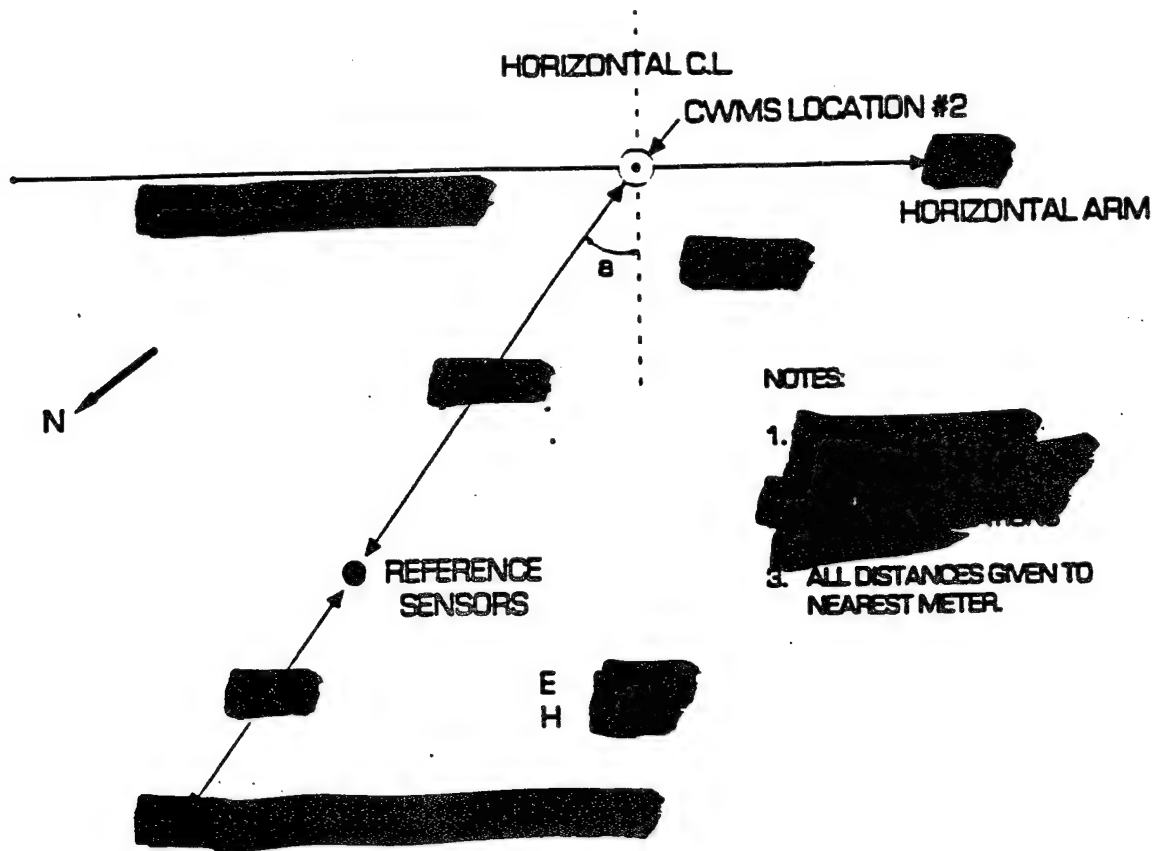
File Designation	Date	Description and Comments
[REDACTED]		V prefix: vertical polarization; H prefix: horizontal polarization
[REDACTED]	1 Jun	Hy/Ez [REDACTED]
[REDACTED]	1 Jun	Repeat VR9 at -12 dBm source
[REDACTED]	2 Jun	NG, amplifier drop-out; noise ok
[REDACTED]	2 Jun	VRA6, 50 ohms, 13 m live reference
[REDACTED]	2 Jun	NG, used V091 stored reference
[REDACTED]	2 Jun	Set up but not run
[REDACTED]	3 Jun	Repeat VR9A
[REDACTED]	3 Jun	Repeat V091; VRA6, short circuit
[REDACTED]	3 Jun	Repeat V092 with 1 m reference
[REDACTED]	3 Jun	Repeat V092A
[REDACTED]	3 Jun	Repeat V091a
[REDACTED]	3 Jun	[REDACTED]
[REDACTED]	3 Jun	[REDACTED]
[REDACTED]	3 Jun	[REDACTED]
[REDACTED]	3 Jun	[REDACTED]
[REDACTED]	3 Jun	Repeat V091U; pick-up noise [REDACTED]
[REDACTED]	4 Jun	Hy/Ez for [REDACTED] #10
[REDACTED]	4 Jun	[REDACTED] #10, short circuit
[REDACTED]	4 Jun	[REDACTED] #10, 50 ohms
[REDACTED]	4 Jun	Pick-up noise in [REDACTED]
[REDACTED]	4 Jun	Hy reference response function at 15 m from CWMS for #9
[REDACTED]	4 Jun	Hy reference response function at 63 m from CWMS for #9
[REDACTED]	4 Jun	[REDACTED] #9, short circuit
[REDACTED]	4 Jun	[REDACTED] #9, 50 ohms
[REDACTED]	4 Jun	Hy/Ez for [REDACTED] #9
[REDACTED]	6 Jun	Hy/Ez for [REDACTED] #3
[REDACTED]	6 Jun	[REDACTED] #3, short circuit, 3 m height
[REDACTED]	6 Jun	[REDACTED] #3, 50 ohms, 3 m height

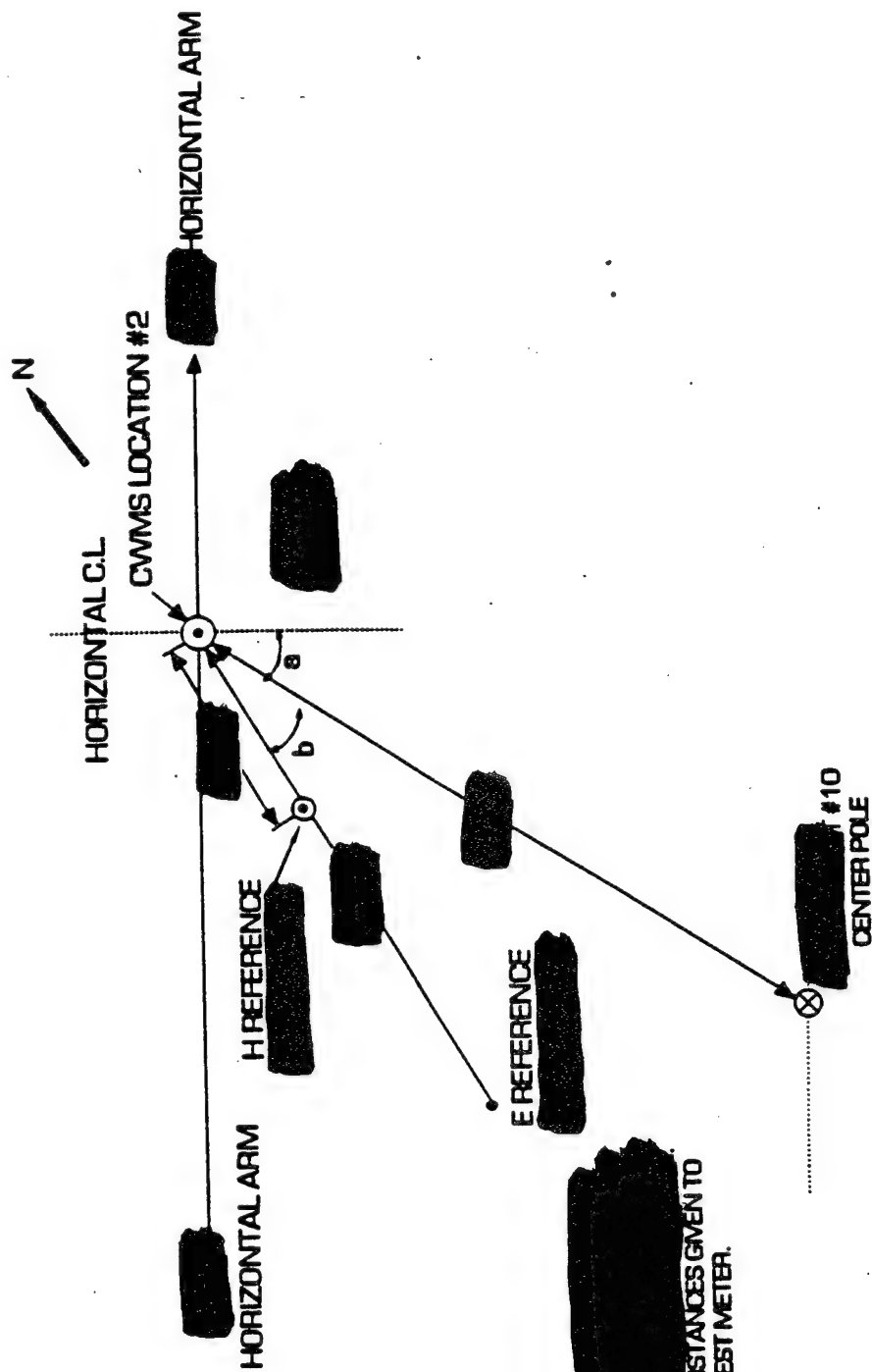
Table 4. CW Data Files (continued)

<u>File Designation</u>	<u>Date</u>	<u>Description and Comments</u>
V prefix: vertical polarization; H prefix: horizontal polarization		
[REDACTED]	9 Jun	Ey/Hz; Ey at 1 m [REDACTED], Hz at 13 m
	9 Jun	Hx/Ey for [REDACTED] 10 horizontal polarization
	9 Jun	[REDACTED] #10, short circuit, auto-noise
	9 Jun	[REDACTED] #10, 50 ohms, V042 noise
	9 Jun	NG Hx used for ref
	9 Jun	NG Hx used for ref
	9 Jun	Pick-up noise [REDACTED]
	9 Jun	[REDACTED]
[REDACTED]	10 Jun	[REDACTED], short circuit, "live" 13 m reference
	10 Jun	[REDACTED] #9, 50 ohms, "live" 13 m reference
	10 Jun	Hz response function at 1 m at H031 "live" Hz 1m ref location
	10 Jun	Ey response function at 3 m at H0 [REDACTED]
[REDACTED]	11 Jun	Hz/Ey for [REDACTED] short circuit
	11 Jun	[REDACTED] 50 ohms
	11 Jun	VRA6, short circuit
	11 Jun	VRA6, 50 ohms
	11 Jun	[REDACTED] short circuit; ref may be NG > [REDACTED]
	11 Jun	[REDACTED] 50 ohms
[REDACTED]	15 Jun	Hz/Ey for [REDACTED] #11 and #12
	15 Jun	[REDACTED] #11, short circuit
	15 Jun	[REDACTED] #11, 50 ohms
	15 Jun	[REDACTED] #12, short circuit
	15 Jun	[REDACTED] #12, 50 ohms
[REDACTED]	16 Jun	Hz/Ey for [REDACTED]
	16 Jun	Ey (at 13 m) response function w/noise
	16 Jun	Hx/Ey for [REDACTED]; USE HRI
	16 Jun	[REDACTED], short circuit; Hz "live" reference
	16 Jun	[REDACTED], 50 ohms; Hz "live" reference
	16 Jun	[REDACTED] 50 ohms
[REDACTED]	16 Jun	short circuit

Table 4. CW Data Files (concluded)

<u>File Designation</u>	<u>Date</u>	<u>Description and Comments</u>
	17 Jun	Field map at 13 m Ez/Hz; (Hz at 1m)
	17 Jun	Field map at 13 m Ey/Hz; (Hz at 1m)
	17 Jun	Field map at 13 m Ex/Hz; (Hz at 1m)
	17 Jun	Field map at 13 m Hx/Ey; (Ey at 1m)
	17 Jun	Field map at 13 m Hy/Ey; (Ey at 1m)
	17 Jun	Field map at 13 m Hz/Ey; (Ey at 1m)





NOTES:

1. [REDACTED]
2. [REDACTED]
3. ALL DISTANCES GIVEN TO NEAREST METER.

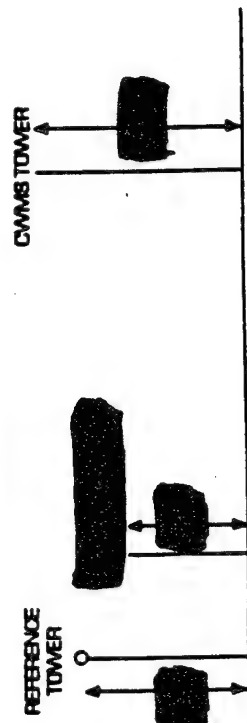
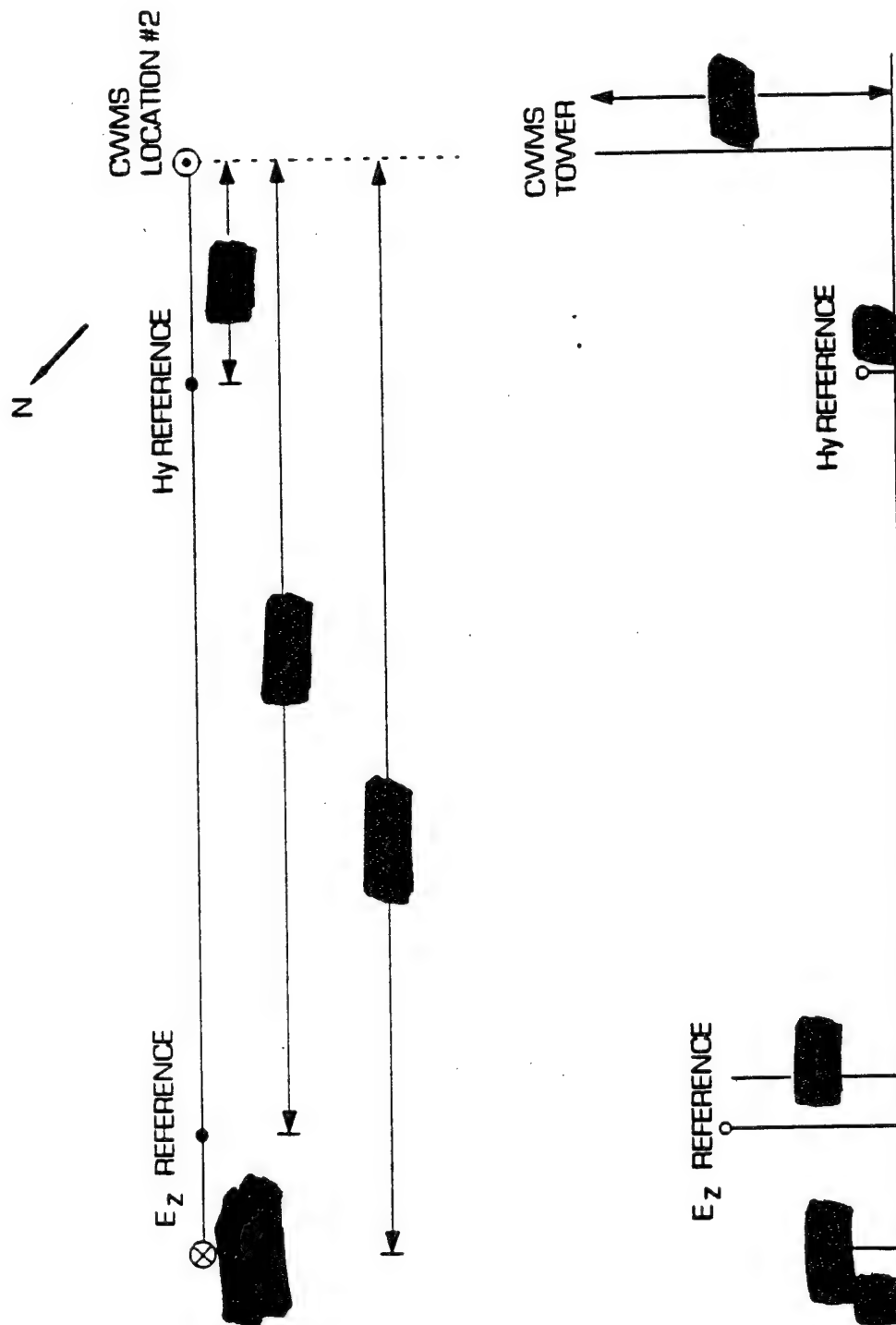


Figure 8. Geometry for [REDACTED] # 10



NOTES:

1. [REDACTED]
2. [REDACTED]
3. ALL DISTANCES TO NEAREST METER.

Figure 9. Geometry

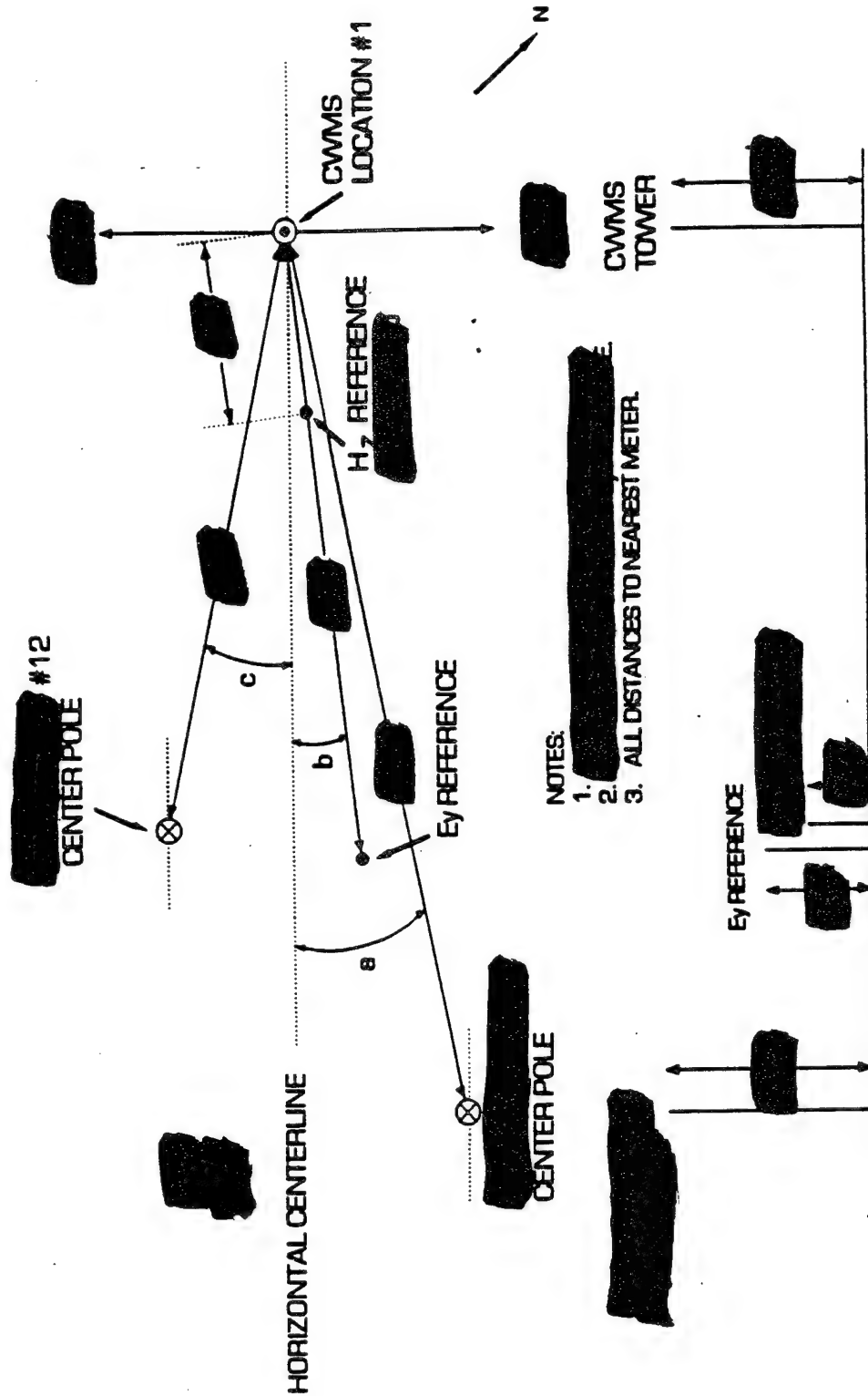
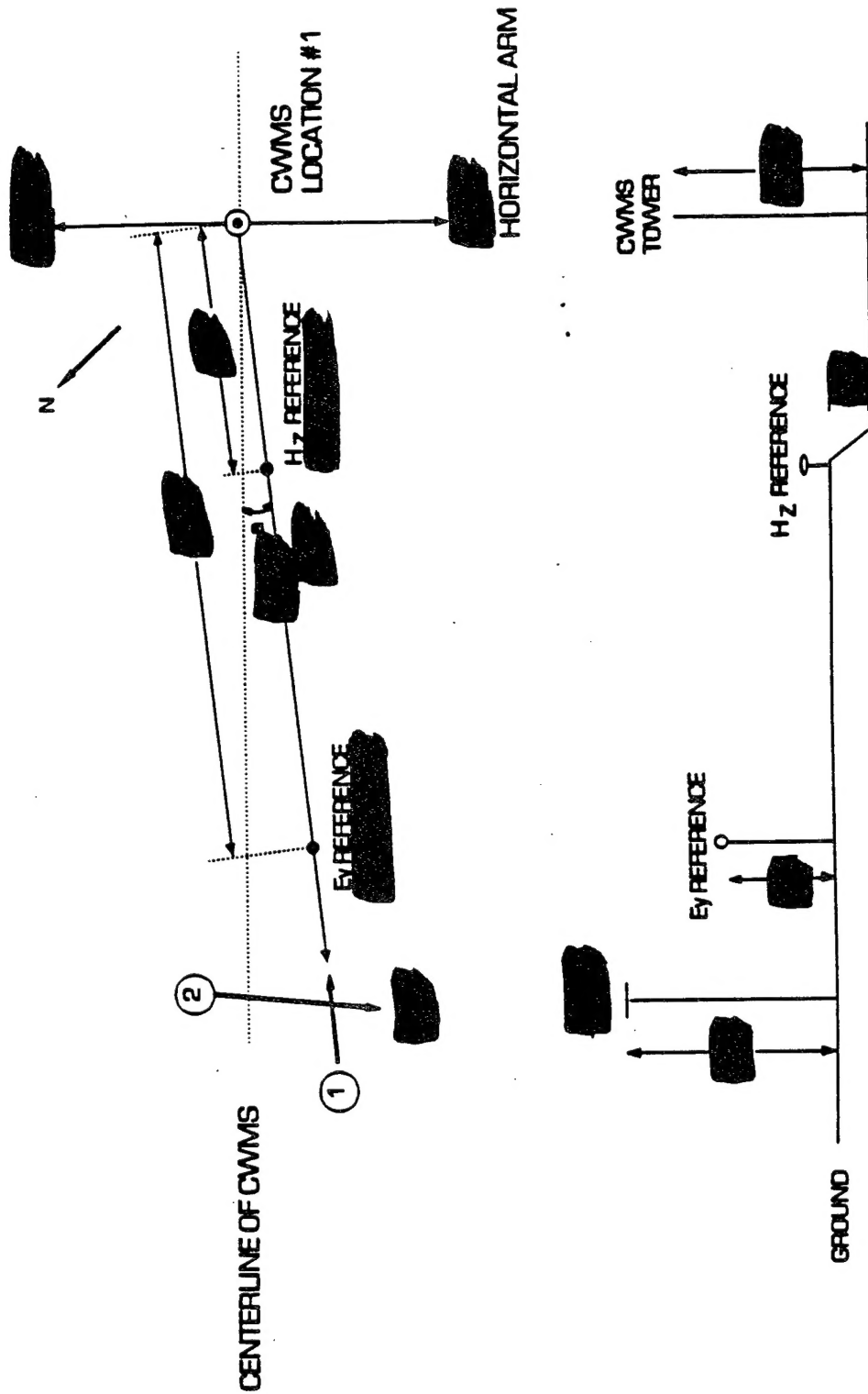


Figure 10. Geometry for [REDACTED] # 11 and # 12



NOTES:

1. POINTING DIRECTION
2. CWMS UP ON CENTERLINE
3. HORIZONTAL POLARIZATION ONLY
4. ALL DISTANCES TO NEAREST METER

Figure 11. Geometry for [REDACTED] Antenna

SECTION 5

RECOMMENDATIONS AND LESSONS LEARNED

5.1 E3 Simulation

- The test demonstrated the feasibility of conducting E3 simulation tests at an operational facility. Hazards to personnel and facility equipment can be minimized, although never totally eliminated due to the nature of the threat environment, if proper procedures are followed.

- [REDACTED] The operator during the [REDACTED] test stood on a ladder to control the pulser. He was exposed to the elements for long periods of time. Such an operational procedure can lead to fatigue and possible error which considering the energies involved could be catastrophic. [REDACTED]

- In addition to the [REDACTED] operator, a second operator was needed to visually observe the position of the [REDACTED]

- The data acquisition system employed [REDACTED] served the purpose required frequent and extended periods for data archiving. *If the E3 pulser is to be employed for an extended facility test, the data storage capability should be improved.* [REDACTED]

- A means to [REDACTED] should be included in the data acquisition system.

- [REDACTED]

5.2 E2 Simulation

- The [REDACTED] tests demonstrated that it is feasible to conduct E2 tests at an actual facility [REDACTED].

- [REDACTED]

- [REDACTED]

5.3 CW Testing

- Many problems were encountered in using the 13 m reference tower. These were mostly due to lack of general familiarity with the unit. *Time should be devoted to establishing a standard operational procedure for the use of the tower.*

- [REDACTED]

- The drop-out of the RF amplifier resulted in great apprehension to use the stored reference feature of the system. The process of switching sensors for a "live" reference is time consuming and sometimes inefficient, e.g. when they are located 13 meters above ground. [REDACTED]

REFERENCES

1. MIL-STD-188-125, High-Altitude Electromagnetic Pulse Protection for Ground-Based C4I Facilities Performing Critical, Time-Urgent Missions, 26 June 1990.
2. DOD-STD-2169A, High-Altitude Electromagnetic Pulse Environment (U) (document is classified Secret).
3. Detailed Test Plan for the HEMP Simulation Test [REDACTED]
T. J. Zwolinski, 20 April 1992.